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Materials Aerometric Database for Use in Developing Materials Damage Functions

Computer Sciences Corp.
Research Triangle Park, NC

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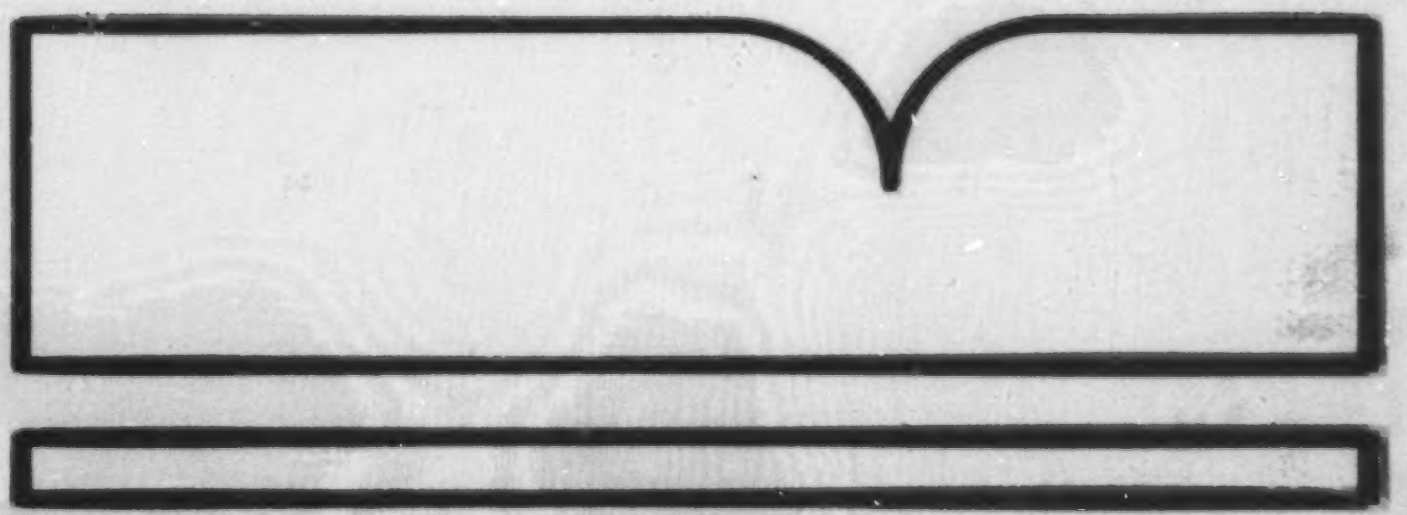

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MATERIALS AEROMETRIC DATABASE FOR USE IN DEVELOPING MATERIALS DAMAGE FUNCTIONS

by

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ABSTRACT

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SECTION 1

INTRODUCTION

USEPA's Atmospheric Research and Exposure Assessment Laboratory (AREAL) has undertaken the task of maintaining the Materials Aerometric Database (MAD), which consists of air quality and meteorological data from five test sites to be used in developing damage functions for the National Acid Precipitation Assessment Program (NAPAP) Materials Assessment Program. The research objectives for this project are as follows:

(1) To accumulate and organize an aerometric database (MAD) containing air quality data and meteorological measurements made at five primary field sites.

- Develop a uniform format for the MAD data.
- Provide validated tapes of the MAD data to the principal investigators within the Materials and Cultural Effects Task Group (Task Group VII).
- Acquire quality assurance/quality control (QA/QC) data from the site operators.
- Monitor the independent systems and performance audits of the sites, conducted by Research Triangle Institute (Shores, 1985-1988).

(2) To enhance the database and allow its use in continuous-damage models by making reasonable predictions for missing data points (infilling).

- Acquire secondary-source data for infilling missing primary-source data.
- Provide data tapes of the enhanced air quality and meteorological data to the principal investigators within Task Group VII.

SECTION 2

TECHNICAL APPROACH

Five materials exposure sites were chosen for continuously recording air quality, meteorology, particle loadings and chemistry, and rain chemistry measurements (Figure 1):

• Adirondack Ecological Center	Newcomb, NY
• Bell Communications Research Center	Chester, NJ
• County Services Building	Steubenville, OH
• West End Library	Washington, DC
• Research Triangle Institute	Research Triangle Park, NC

The following variables were measured in order to quantitatively evaluate the deposition of acids on the materials samples:

Meteorological Variables

- Wind speed average (WSA)
- Wind direction average (WDA)
- Wind direction vector (WDV)
- Temperature (TP)
- Dew point (DP)
- Relative humidity (RH)
- Precipitation (PR)
- Solar radiation (SR)

Air Quality Variables

- Sulfur dioxide (SO_2)
- Ozone (O_3)
- Oxides of nitrogen (NO_x)
- Nitric oxide (NO)
- Nitrogen dioxide (NO_2)

The data were supplied to the EPA in a variety of site-dependent formats. The format used by the Research Triangle Park site was chosen as the standard data storage format (Figure 2), and software was developed to convert all other sites' data to this format.

```
Col. no.:  1         2         3         4         5         6         7         8
           12345678901234567890123456789012345678901234567890123456789012345678901234567890

           286 043 03  26  15F  3  18  13  320  33  -12  -91  550  0  0  319 9999
           286 043 04  24  13   3  16  15  318  33  -17  -95  553  0  0  318 9999

Contents:  YR DAY HR   SO2 NO2  NO NOX O3  WDA  WSA TP   DP   RH   PR SR WDV WSV
```

Additional information:

Column 1 contains the site ID (1=DC, 2=NC, 3=NJ, 4=NY, 5=OH).
Columns 5-7 contain the Julian date.
Column 21 contains an example information flag (discussed below); all are non-numerical characters, except the minus sign.
WSV stands for wind speed vector, a variable reported by only the New York site.

Figure 2. Format for storage of all MAD data (based on the format for the RTP, NC, site).

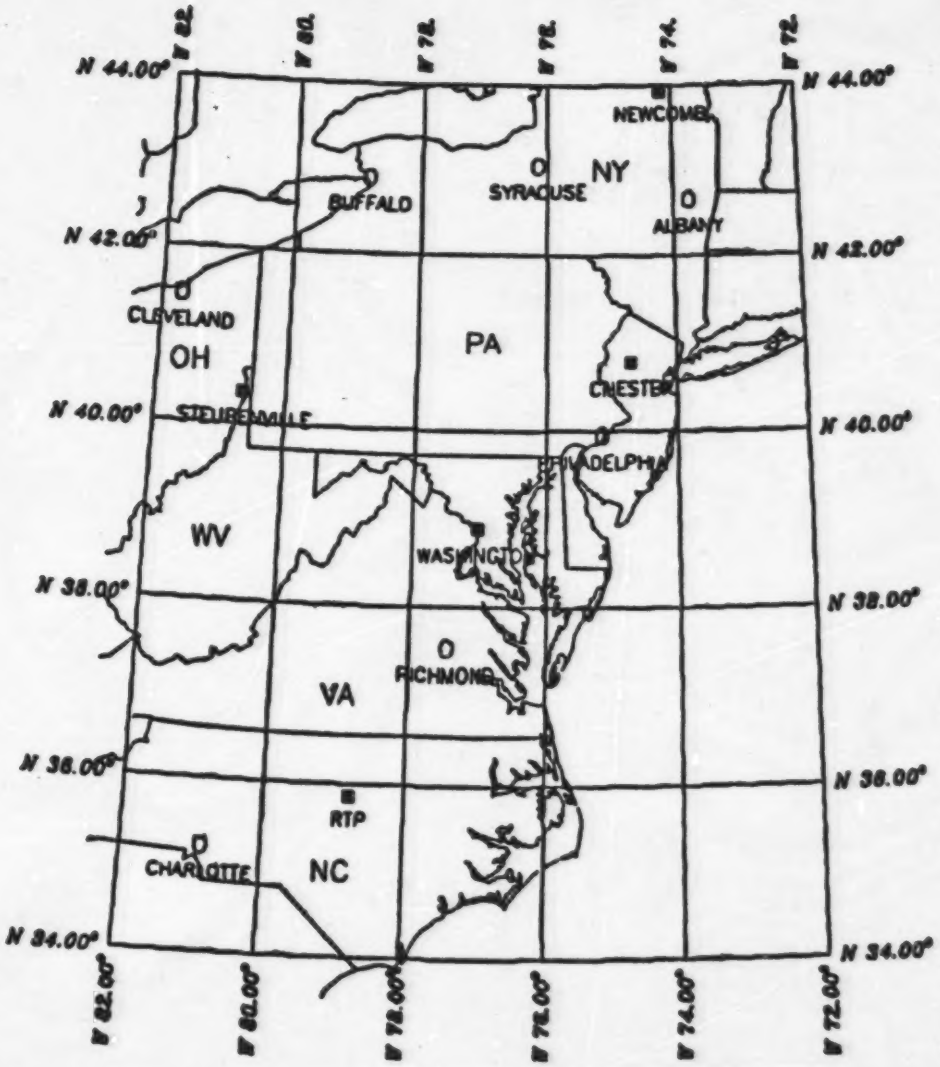

Figure 1. Locations of the five materials exposure test sites (marked with solid squares).

During the project, some of the data have been lost due to equipment shortages and failures, power outages, etc. A number of secondary sources were found to replace the missing data. These sites were located near the primary sites with similar micrometeorology and are listed in Table 1 with the types of variables recorded at each site.

TABLE 1. SECONDARY MAD DATA SOURCES

Primary Site	Corresponding Secondary Site(s)	Variables Measured
Newcomb, NY	State University of New York site 1 km away from primary site	Meteorology
Chester, NJ	Bell Core Lab, Chester, NJ	Meteorology
Steubenville, OH	Harvard School of Public Health Study site in Steubenville, OH	Meteorology, air quality
	NOVAA, Mingo Junction, OH	Meteorology
Washington, DC	Washington National Airport	Meteorology
Research Triangle Park, NC	Raleigh-Durham Airport	Meteorology
	USEPA, Research Triangle Park, NC	Meteorology, air quality

Each site performed ongoing QA on its own systems and data, based on the format outlined in 40 CFR 58, Appendix A (CFR, 1982). Also, an independent audit team from the Research Triangle Institute (RTI) has conducted annual or semiannual performance and system audits at the sites since 1985 (Shores, 1985-1988).

As the raw data were received, we performed preliminary statistical analysis and quality assurance checks, identified data problems, and contacted the site operators about them. Wherever possible, these problems were corrected and problem data were replaced by the site.

Using secondary-source data (if available) to infill primary-source data is the most reliable method of infilling, as long as the correlation between them is good and any bias can be removed. We used secondary-source substitution whenever possible, before using alternative forms of infilling. For missing meteorological data, we used only secondary-source substitution, because infilling this type of data using predictions from any form of calculations could corrupt the database. For missing air quality data, however, we employed three predictive infilling methods when no acceptable secondary-source data were available: linear interpolation using good data on either side of the gap; regression using a long-term least-squares prediction; and daytime or nighttime averages each compiled from a month's worth of data.

We performed a preliminary survey of the NC data to evaluate the occurrences of missing data. For a given year and variable, we recorded the gap length for each instance of missing data and then developed histograms of this information. In most cases, the data displayed a peak at one hour and then dropped off quickly after two or three hours, as shown in the example in Table 2.

TABLE 2. MISSING-DATA GAP-LENGTH FREQUENCIES FOR 1984 RTP, NC, AIR QUALITY DATA

Gap Length (h)	Number of Gaps in a Variable's Data				
	O_3	SO_2	NO	NO_x	NO_2
1	31	19	12	16	13
2	10	15	5	4	5
3	2	6	3	3	4
4-6	4	15	4	4	4
7-12	5	6	1	1	0
13-24	4	4	1	1	2
>24	6	8	2	2	2

We decided to take the most conservative approach to infilling the data. For one-hour and two-hour gaps, we used interpolation. After these were infilled, the remaining gaps of three or more hours were infilled using a regression prediction, if the R^2 for the regression equation was greater than 0.50. We then infilled any gaps still remaining with the appropriate daytime or nighttime monthly average. Listed below is a summary of the steps we followed in processing each subset of the database to produce the final enhanced database:

Step 1. <u>For both meteorological and air quality data</u>:

Replace all missing data, data below detectable limits, or data above reasonable limits with acceptable secondary-source data, if the correlation between primary- and secondary-source data is high ($r^2 > 0.95$). Use the following mathematical replacement:

$$X_{prim}(t) = X_{sec}(t) + \text{(the difference in their yearly averages)}$$

Step 2. <u>For air quality data only</u>:

For one-hour or two-hour gaps remaining after Step 1, infill with a smoothed value interpolated from the points before and after the gap. For gaps three or more hours long, use regression* to replace the data if R^2 for the regression equation is greater than 0.50; otherwise, replace missing data with daytime or nighttime monthly averages (where daytime includes hourly data from 7 A.M. to 6 P.M. and nighttime includes data from 7 P.M. to 6 A.M.).

*Using SAS and the yearly data, produce a multiple regression using (1) all of the air quality and meteorological variables except wind direction and (2) a diurnal variable equal to $\sin(15.0 \cdot h_n)$, where h_n is the nth hour of the day (n = 1 to 24).

Step 3. Apply the following special corrections as needed:

- Set solar radiation to zero at night, if not already zero.
- For air quality data only, smooth infilled data into measured data to avoid abrupt slope discontinuities. Use a five-time-step smoothing scheme for infilling done with multiple regressions, secondary-source data, and monthly averages; do not use for infilling done with one- and two-hour interpolations.
- Maintain the NO_x, NO, and NO_2 balance using:

  $$Conc(NO_x) = Conc(NO) + Conc(NO_2)$$

An information flag accompanies every data point in the MAD. The flag is a blank for original, untouched data. If the data were modified or infilled, this flag is set to a code describing the infilling method. (The flags are discussed in Tang et al., July 1988.)

SECTION 3

RESULTS

Detailed descriptions of the raw data statistics and the site operations for all sites are presented in Tang et al. (April 1988). Tables 3a, 4a, 5a, 6a, and 7a present raw-data summary statistics for all five sites.

We processed the raw meteorological and air quality data from each site using the steps discussed above, and then performed statistical analyses on the enhanced MAD (Tang et al., July 1988). Tables 3b, 4b, 5b, 6b, and 7b present summary statistics for the infilled data for all five sites.

SECTION 4

DISCUSSION

The MAD is now available for use in predicting damage functions. The raw and enhanced MAD data tapes contain the data for all sites over part or all of the 1982-1988 period. The missing air quality data have been infilled using the algorithm discussed above. However, we could not find secondary sources for all of the sites, so there are gaps in the meteorological data. The use of modeled meteorological data in the development of the damage functions could seriously bias the predicted data values and the statistics that describe them.

Also, we have already found a bias in the data from two sites. For data values below the minimum detectable limit (MDL), the DC site has been reporting the MDL and the NJ site has reported one-half the MDL. This is acceptable for some EPA uses, but we are currently trying to acquire the unmodified data.

SECTION 5

CONCLUSIONS

We have developed an enhanced database that will provide materials assessment investigators with a comprehensive data set of meteorological and air quality data collected during materials test exposures. Two tapes, one containing the raw data rewritten in a uniform format and the second containing the enhanced database, have been provided to the principal investigators within Task Group VII. The MAD provides essential data for developing damage functions to be used in estimating current materials damage due to acid rain, predicting future damage, and aiding in the development of control scenarios. NAPAP will use this information to develop reports to Congress.

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TABLE 3A. SUMMARY STATISTICS FOR THE RAW MAD FOR THE NEWCOMB, NY, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1983	Mean (ppm)	0.029	0.003	0.008	0.011	0.011	0.64	5.22	-	82.58	-	-
	Std. Dev.	0.015	0.003	0.023	0.024	0.031	1.16	11.09	-	20.89	-	-
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-30.10	-	18.30	-	-
	Max.	0.104	0.044	0.101	0.106	0.337	10.00	31.80	-	101.60	-	-
	% Missing	19.9	20.3	79.1	80.7	78.1	32.7	2.0	-	9.5	-	-
1984	Mean (ppm)	0.031	0.003	0.000	0.002	0.001	0.74	6.19	-	82.92	0.14	2.00
	Std. Dev.	0.016	0.004	0.002	0.004	0.003	1.10	11.36	-	20.02	0.86	5.46
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-28.30	-	17.70	0.00	0.00
	Max.	0.127	0.043	0.034	0.080	0.056	8.00	31.60	-	100.60	26.60	38.25
	% Missing	2.6	3.7	9.9	9.9	9.8	37.0	35.4	-	20.7	85.6	91.6
1985	Mean (ppm)	0.029	0.002	0.001	0.001	0.001	0.93	8.79	-	83.79	0.14	11.30
	Std. Dev.	0.014	0.003	0.002	0.003	0.001	0.78	12.41	-	20.20	1.15	19.56
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-27.10	-	15.40	0.00	0.00
	Max.	0.095	0.028	0.062	0.119	0.027	6.90	33.90	-	100.90	28.00	96.18
	% Missing	2.7	1.5	27.1	27.3	27.1	1.4	18.4	-	11.5	2.2	1.8
1986	Mean (ppm)	0.030	0.002	0.001	0.002	0.002	0.85	6.43	1.28	71.62	0.11	10.43
	Std. Dev.	0.014	0.003	0.001	0.002	0.002	0.76	11.71	10.52	21.59	0.91	18.71
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-27.80	-17.80	12.00	0.00	0.00
	Max.	0.099	0.029	0.008	0.026	0.021	9.70	34.80	25.80	100.00	25.00	98.75
	% Missing	3.1	2.4	33.7	36.0	35.1	4.6	4.4	1.7	8.5	3.4	11.8
1987	Mean (ppm)	0.031	0.002	0.001	0.002	0.002	0.97	2.29	2.82	-	0.12	11.47
	Std. Dev.	0.016	0.003	0.002	0.004	0.002	0.74	11.83	10.12	-	1.04	19.33
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-17.80	-17.60	-	0.00	0.00
	Max.	0.108	0.024	0.036	0.160	0.025	8.00	33.30	162.80	-	29.70	95.44
	% Missing	4.3	7.3	3.9	4.2	4.0	17.9	11.5	50.8	-	12.2	11.4

TABLE 3B. SUMMARY STATISTICS FOR THE ENHANCED MAD FOR THE NEWCOMB, NY, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1983	Mean (ppm)	0.029	0.003	0.002	0.005	0.003	0.64	5.22	1.31	82.57	-	-
	Std. Dev.	0.013	0.003	0.011	0.026	0.015	1.16	11.09	10.04	20.88	-	-
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-30.10	-31.10	18.30	-	-
	Max.	0.104	0.044	0.101	0.438	0.337	10.00	31.80	25.70	100.00	-	-
	% Missing	0.0	0.0	0.0	0.0	0.0	32.7	1.9	9.6	9.4	-	-
1984	Mean (ppm)	0.031	0.003	0.000	0.002	0.001	0.74	6.19	2.61	82.92	0.14	0.40
	Std. Dev.	0.016	0.004	0.002	0.004	0.003	1.10	11.64	10.96	20.02	0.86	2.57
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-28.30	-32.10	17.70	0.00	0.00
	Max.	0.127	0.043	0.034	0.080	0.056	8.00	31.60	24.40	100.00	25.40	38.25
	% Missing	0.0	0.0	0.0	0.0	0.0	36.9	35.3	37.3	20.7	85.6	57.5
1985	Mean (ppm)	0.029	0.002	0.000	0.001	0.001	0.93	8.79	4.66	83.78	0.14	11.22
	Std. Dev.	0.014	0.003	0.001	0.002	0.001	0.79	12.40	11.77	20.21	1.15	19.56
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-27.10	-28.20	15.40	0.00	0.00
	Max.	0.095	0.028	0.062	0.063	0.027	6.90	33.90	30.00	100.00	28.00	96.18
	% Missing	0.0	0.0	0.0	0.0	0.0	1.1	18.2	27.6	11.4	2.2	0.7
1986	Mean (ppm)	0.030	0.002	0.000	0.003	0.002	0.86	6.41	1.12	72.79	0.11	9.88
	Std. Dev.	0.014	0.003	0.001	0.002	0.002	0.76	11.69	10.66	21.90	0.91	18.36
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-27.80	-27.80	12.00	0.00	0.00
	Max.	0.099	0.029	0.008	0.026	0.021	9.70	34.60	23.20	100.00	25.00	98.75
	% Missing	0.0	0.0	0.0	0.0	0.0	2.8	2.8	1.0	3.4	3.4	5.5
1987	Mean (ppm)	0.031	0.002	0.001	0.002	0.002	0.97	2.19	2.59	74.46	0.12	11.09
	Std. Dev.	0.016	0.003	0.002	0.003	0.002	0.73	11.74	9.87	21.20	1.04	19.59
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-18.20	-18.40	8.70	0.00	0.00
	Max.	0.108	0.024	0.036	0.039	0.025	8.00	33.30	24.10	100.00	29.70	99.00
	% Missing	0.0	0.0	0.0	0.0	0.0	14.4	7.8	48.7	49.3	12.2	6.2

TABLE 4A. SUMMARY STATISTICS FOR THE RAW MAD FOR THE CHESTER, NJ, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1982	Mean (ppm)	0.034	0.007	0.004	0.014	0.011	2.32	-5.52	-	57.66	0.10	13.32
	Std. Dev.	0.024	0.009	0.011	0.020	0.011	1.93	5.88	-	18.18	0.70	20.97
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-19.40	-	12.80	0.00	0.00
	Max.	0.184	0.051	0.140	0.200	0.083	24.60	17.60	-	98.60	24.00	86.20
	% Missing	11.3	36.6	43.7	44.1	44.1	3.9	95.1	-	51.3	10.1	11.0
1983	Mean (ppm)	0.033	0.007	0.005	0.019	0.014	2.58	7.91	-	68.55	0.16	12.16
	Std. Dev.	0.024	0.008	0.006	0.014	0.010	1.88	12.57	-	22.85	0.85	19.38
	Min.	0.001	0.001	0.002	0.006	0.003	0.00	-54.70	-	-0.60	0.00	0.00
	Max.	0.253	0.124	0.097	0.153	0.077	12.10	32.40	-	103.10	29.00	81.20
	% Missing	11.2	17.3	30.8	30.9	30.5	7.8	15.7	-	21.2	10.1	10.1
1984	Mean (ppm)	0.030	0.009	0.006	0.023	0.017	2.61	9.28	1.59	72.39	0.15	12.10
	Std. Dev.	0.020	0.010	0.009	0.018	0.012	3.07	9.66	8.02	20.33	1.05	19.68
	Min.	0.001	0.001	0.001	0.006	0.003	0.00	-18.00	-18.20	20.70	0.00	0.00
	Max.	0.147	0.121	0.122	0.205	0.108	36.90	34.90	36.90	102.60	31.00	81.80
	% Missing	10.3	15.3	11.6	11.6	10.1	0.7	10.1	73.5	15.9	1.2	1.3
1985	Mean (ppm)	0.033	0.006	0.009	0.023	0.014	2.68	9.58	1.35	-	0.13	11.50
	Std. Dev.	0.021	0.008	0.015	0.023	0.011	3.14	10.25	10.31	-	1.18	19.81
	Min.	0.001	0.001	0.001	0.002	0.001	0.00	-23.80	-29.10	-	0.00	0.00
	Max.	0.126	0.188	0.279	0.397	0.118	36.90	45.90	46.10	-	78.00	83.90
	% Missing	7.2	9.7	10.0	10.5	10.5	3.4	5.8	10.3	-	4.0	4.0
1986	Mean (ppm)	0.032	0.006	0.010	0.025	0.014	-	-	-	-	-	-
	Std. Dev.	0.022	0.007	0.011	0.018	0.010	-	-	-	-	-	-
	Min.	0.001	0.001	0.000	0.003	0.003	-	-	-	-	-	-
	Max.	0.135	0.125	0.144	0.207	0.098	-	-	-	-	-	-
	% Missing	7.0	10.0	10.9	10.9	9.8	-	-	-	-	-	-
1987	Mean (ppm)	-	0.005	0.005	-	0.014	-	-	-	-	-	-
	Std. Dev.	-	0.007	0.006	-	0.010	-	-	-	-	-	-
	Min.	-	0.001	0.001	-	0.002	-	-	-	-	-	-
	Max.	-	0.140	0.142	-	0.081	-	-	-	-	-	-
	% Missing	100.0	31.3	12.3	100.0	12.2	-	-	-	-	-	-

TABLE 4B. SUMMARY STATISTICS FOR THE ENHANCED MAD FOR THE CHESTER, NJ, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1982	Mean (ppm)	0.034	0.007	0.004	0.017	0.013	2.32	-5.51	-	57.61	0.10	12.76
	Std. Dev.	0.023	0.008	0.009	0.016	0.009	1.91	5.88	-	18.22	0.70	20.69
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-19.40	-	0.00	0.00	0.00
	Max.	0.184	0.052	0.140	0.200	0.083	18.50	17.60	-	98.60	24.00	86.20
	% Missing	0.0	0.0	0.0	0.0	0.0	3.5	95.1	-	51.0	10.1	6.9
1983	Mean (ppm)	0.032	0.007	0.005	0.020	0.015	2.58	7.91	1.97	68.52	0.16	11.67
	Std. Dev.	0.023	0.007	0.005	0.012	0.008	1.88	12.56	12.97	22.77	0.85	19.15
	Min.	0.001	0.000	0.000	0.004	0.002	0.00	-54.70	-59.10	0.80	0.00	0.00
	Max.	0.253	0.124	0.097	0.153	0.077	12.10	32.40	23.90	100.00	29.00	81.20
	% Missing	0.0	0.0	0.0	0.0	0.0	7.8	15.5	24.2	20.9	10.1	6.2
1984	Mean (ppm)	0.030	0.009	0.006	0.023	0.017	2.61	9.28	3.74	72.32	0.15	12.05
	Std. Dev.	0.020	0.009	0.008	0.017	0.011	3.07	9.66	9.86	20.34	1.05	19.65
	Min.	0.000	0.000	0.000	0.006	0.003	0.00	-18.00	-22.90	20.70	0.00	0.00
	Max.	0.147	0.121	0.122	0.205	0.108	36.90	34.90	36.90	100.00	31.00	81.80
	% Missing	0.0	0.0	0.0	0.0	0.0	0.7	10.0	20.0	15.7	1.2	0.8
1985	Mean (ppm)	0.033	0.006	0.008	0.022	0.014	2.68	9.58	1.34	59.54	0.13	11.33
	Std. Dev.	0.021	0.008	0.014	0.022	0.010	3.14	10.24	10.29	16.95	1.18	19.71
	Min.	0.000	0.000	0.000	0.002	0.000	0.00	-23.80	-29.10	18.80	0.00	0.00
	Max.	0.126	0.188	0.279	0.397	0.118	36.90	31.50	24.30	98.20	78.00	83.90
	% Missing	0.0	0.0	0.0	0.0	0.0	3.4	5.8	10.3	10.3	4.0	2.6
1986	Mean (ppm)	0.032	0.006	0.011	0.025	0.014	2.10	10.01	3.15	59.54	0.10	12.79
	Std. Dev.	0.022	0.007	0.010	0.017	0.009	1.31	9.63	11.52	24.15	0.77	19.78
	Min.	0.001	0.000	0.000	0.003	0.001	0.00	-17.40	-35.00	0.00	0.00	0.00
	Max.	0.135	0.125	0.144	0.207	0.098	8.60	33.40	25.00	100.00	30.50	82.84
	% Missing	0.0	0.0	0.0	0.0	0.0	5.7	5.7	40.4	38.3	5.8	3.3
1987	Mean (ppm)	0.034	0.007	0.005	0.020	0.015	2.06	10.69	4.10	67.09	0.10	13.06
	Std. Dev.	0.021	0.007	0.006	0.014	0.010	1.32	9.91	10.47	18.48	0.77	19.64
	Min.	0.000	0.000	0.000	0.003	0.000	0.00	-18.30	-24.40	21.90	0.00	0.00
	Max.	0.162	0.140	0.142	0.175	0.081	9.00	33.20	25.70	100.00	27.70	80.53
	% Missing	0.0	0.0	0.0	0.0	0.0	0.1	0.1	22.3	22.3	0.1	0.1

TABLE 5A. SUMMARY STATISTICS FOR THE RAW MAD FOR THE STEUBENVILLE, OH, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1985	Mean (ppm)	0.016	0.021	0.013	-	0.019	1.73	10.35	-	74.21	-	-
	Std. Dev.	0.015	0.025	0.022	-	0.011	1.36	11.24	-	21.08	-	-
	Min.	0.000	0.000	0.000	-	0.000	0.00	-31.00	-	17.00	-	-
	Max.	0.090	0.325	0.025	-	0.125	13.40	36.70	-	100.00	-	-
	% Missing	1.8	4.2	12.6	100.0	2.6	1.7	17.8	-	22.4	-	-
1986	Mean (ppm)	0.019	0.022	-	-	0.020	1.27	11.99	-	79.19	-	-
	Std. Dev.	0.018	0.029	-	-	0.014	1.00	10.37	-	17.07	-	-
	Min.	0.000	0.000	-	-	0.000	0.00	-71.00	-	25.00	-	-
	Max.	0.260	0.500	-	-	0.154	6.70	35.00	-	100.00	-	-
	% Missing	1.6	6.0	100.0	100.0	5.3	0.1	0.3	-	74.9	-	-
1987	Mean (ppm)	0.016	0.022	0.025	0.045	0.020	1.32	12.40	-	71.35	0.12	5.01
	Std. Dev.	0.017	0.031	0.030	0.038	0.013	1.29	10.89	-	19.64	1.26	9.68
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-48.00	-	17.00	0.00	0.00
	Max.	0.119	0.364	0.362	0.396	0.265	8.00	324.00	-	100.00	38.40	52.20
	% Missing	4.4	4.5	2.8	2.8	0.7	0.1	8.3	-	0.1	80.3	80.3

TABLE 5B. SUMMARY STATISTICS FOR THE ENHANCED MAD FOR THE STEUBENVILLE, OH, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1985	Mean (ppm)	0.016	0.021	0.013	0.032	0.019	1.73	10.36	8.36	74.19	-	-
	Std. Dev.	0.014	0.025	0.021	0.027	0.011	1.36	11.22	8.96	21.11	-	-
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-31.00	-20.60	8.30	-	-
	Max.	0.090	0.325	0.250	0.305	0.125	13.40	36.70	30.40	100.00	-	-
	% Missing	0.0	0.0	0.0	0.0	0.0	1.6	17.5	36.2	22.3	-	-
1986	Mean (ppm)	0.019	0.022	0.011	0.031	0.020	1.27	12.02	4.56	64.00	-	-
	Std. Dev.	0.018	0.029	0.016	0.024	0.013	1.00	10.23	9.76	18.13	-	-
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-16.00	-22.20	15.90	-	-
	Max.	0.260	0.500	0.181	0.221	0.154	6.70	35.00	23.30	100.00	-	-
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	0.4	-	-
1987	Mean (ppm)	0.016	0.022	0.025	0.046	0.020	1.32	12.38	6.89	71.36	0.12	1.95
	Std. Dev.	0.017	0.030	0.030	0.038	0.013	1.29	10.25	9.96	19.64	1.26	6.62
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-18.00	-21.00	17.00	0.00	0.00
	Max.	0.119	0.364	0.362	0.407	0.265	8.00	34.00	24.20	100.00	38.40	52.20
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3	0.0	80.3	51.0

TABLE 6A. SUMMARY STATISTICS FOR THE RAW MAD FOR THE WASHINGTON, DC, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1982*	Mean (ppm)	0.017	0.014	0.032	0.070	0.035	-	-	-	-	-	-
	Std. Dev.	0.018	0.010	0.059	0.069	0.015	-	-	-	-	-	-
	Min.	0.000	0.001	0.001	0.002	0.001	-	-	-	-	-	-
	Max.	0.125	0.099	0.571	0.660	0.122	-	-	-	-	-	-
	% Missing	5.7	6.4	27.1	35.3	35.2	-	-	-	-	-	-
1983	Mean (ppm)	0.019	0.012	0.046	0.079	0.033	-	-	-	-	-	-
	Std. Dev.	0.021	0.010	0.061	0.068	0.014	-	-	-	-	-	-
	Min.	0.000	0.000	0.001	0.012	0.009	-	-	-	-	-	-
	Max.	0.153	0.095	0.541	0.648	0.122	-	-	-	-	-	-
	% Missing	0.3	12.9	3.8	3.9	2.4	-	-	-	-	-	-
1984	Mean (ppm)	0.016	0.011	0.042	0.073	0.031	-	-	-	-	-	-
	Std. Dev.	0.015	0.010	0.067	0.075	0.013	-	-	-	-	-	-
	Min.	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-
	Max.	0.111	0.081	0.680	0.815	0.135	-	-	-	-	-	-
	% Missing	1.9	0.7	1.8	1.8	0.5	-	-	-	-	-	-
1985	Mean (ppm)	0.021	0.008	0.033	0.068	0.035	-	-	-	-	-	-
	Std. Dev.	0.016	0.008	0.055	0.062	0.017	-	-	-	-	-	-
	Min.	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-
	Max.	0.119	0.090	0.614	0.681	0.119	-	-	-	-	-	-
	% Missing	1.6	1.6	1.6	1.6	1.6	-	-	-	-	-	-
1986	Mean (ppm)	0.018	0.012	0.032	0.060	0.028	-	-	-	-	-	-
	Std. Dev.	0.016	0.010	0.050	0.056	0.013	-	-	-	-	-	-
	Min.	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-
	Max.	0.102	0.143	0.545	0.594	0.236	-	-	-	-	-	-
	% Missing	1.8	1.8	1.8	1.8	1.8	-	-	-	-	-	-
1987	Mean (ppm)	0.017	0.012	0.034	-	0.024	-	-	-	-	-	-
	Std. Dev.	0.017	0.009	0.053	-	0.010	-	-	-	-	-	-
	Min.	0.001	0.001	0.001	-	0.001	-	-	-	-	-	-
	Max.	0.128	0.094	0.627	-	0.090	-	-	-	-	-	-
	% Missing	2.3	3.1	11.2	100.0	3.6	-	-	-	-	-	-

*April through December data only.

TABLE 6B. SUMMARY STATISTICS FOR THE ENHANCED MAD FOR THE WASHINGTON, DC, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1982*	Mean (ppm)	0.017	0.014	0.031	0.065	0.034	3.67	18.06	10.50	63.75	0.11	12.13
	Std. Dev.	0.017	0.010	0.051	0.058	0.012	2.02	8.00	8.63	17.29	0.90	19.81
	Min.	0.000	0.000	0.000	0.002	0.001	0.00	-5.60	-15.60	14.30	0.00	0.00
	Max.	0.125	0.099	0.571	0.660	0.122	16.50	35.60	23.90	100.00	27.90	77.40
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.9
1983	Mean (ppm)	0.019	0.012	0.046	0.079	0.033	3.46	14.71	7.17	62.91	0.15	12.09
	Std. Dev.	0.021	0.010	0.060	0.067	0.014	2.08	10.13	10.54	17.43	0.88	20.71
	Min.	0.000	0.000	0.001	0.012	0.009	0.00	-16.10	-27.20	13.40	0.00	0.00
	Max.	0.153	0.095	0.541	0.648	0.122	16.50	38.30	26.10	100.00	32.80	79.00
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.3
1984	Mean (ppm)	0.016	0.011	0.041	0.073	0.031	3.88	14.39	7.68	66.34	0.11	10.74
	Std. Dev.	0.015	0.010	0.067	0.074	0.013	1.98	9.66	10.30	17.68	0.72	21.50
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-15.00	-17.80	16.40	0.00	0.00
	Max.	0.111	0.081	0.680	0.815	0.135	14.40	35.60	25.00	100.00	23.10	80.60
	% Missing	0.0	0.0	0.0	0.0	0.0	1.1	1.1	1.1	1.1	0.0	85.8
1985	Mean (ppm)	0.021	0.008	0.033	0.068	0.035	4.10	14.51	7.29	64.83	0.11	-
	Std. Dev.	0.015	0.008	0.054	0.062	0.017	2.00	10.19	10.83	19.62	0.82	-
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-17.80	-17.80	18.00	0.00	-
	Max.	0.119	0.090	0.614	0.681	0.119	15.40	36.10	25.60	100.00	25.10	-
	% Missing	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.0	-
1986	Mean (ppm)	0.018	0.012	0.032	0.060	0.028	4.32	14.24	7.35	66.60	0.09	-
	Std. Dev.	0.016	0.010	0.050	0.055	0.013	1.92	10.16	10.22	19.86	0.62	-
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-11.10	-17.80	17.00	0.00	-
	Max.	0.102	0.143	0.545	0.594	0.236	14.40	36.10	26.10	100.00	18.50	-
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
1987	Mean (ppm)	0.017	0.012	0.033	0.057	0.024	4.24	14.32	7.49	66.71	0.11	-
	Std. Dev.	0.017	0.009	0.050	0.054	0.010	1.97	10.10	10.51	19.82	0.85	-
	Min.	0.001	0.001	0.001	0.002	0.001	0.00	-17.80	-21.70	0.00	0.00	-
	Max.	0.128	0.094	0.627	0.628	0.090	14.40	37.80	25.60	100.00	31.80	-
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-

*April through December data only.

TABLE 7A. SUMMARY STATISTICS FOR THE RAW MAD FOR THE RESEARCH TRIANGLE PARK, NC, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1982*	Mean (ppm)	0.023	0.001	0.009	0.020	0.011	1.25	16.74	11.04	71.22	0.12	13.12
	Std. Dev.	0.019	0.003	0.022	0.024	0.007	1.11	7.96	8.50	17.19	0.97	19.41
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	0.00	-13.50	24.00	0.0	0.0
	Max.	0.091	0.021	0.225	0.250	0.046	6.80	31.80	22.60	99.40	33.0	76.20
	% Missing	3.3	3.2	1.1	2.2	2.3	31.0	0.4	6.5	6.8	0.0	4.4
1983	Mean (ppm)	0.029	0.003	0.008	0.021	0.013	1.63	14.64	6.86	65.07	0.13	14.03
	Std. Dev.	0.023	0.004	0.019	0.023	0.009	1.30	10.07	9.43	20.22	0.85	21.03
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-16.00	-26.10	16.20	0.0	0.0
	Max.	0.132	0.048	0.295	0.312	0.073	10.00	38.70	23.00	98.60	22.0	78.0
	% Missing	6.5	4.6	3.3	3.3	3.5	0.1	0.9	16.4	17.3	0.0	2.4
1984	Mean (ppm)	0.025	0.004	0.010	0.022	0.012	1.65	15.16	7.79	65.96	0.14	11.38
	Std. Dev.	0.021	0.004	0.024	0.029	0.010	1.20	9.31	9.45	18.85	1.01	17.57
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-12.70	-17.50	13.40	0.0	0.0
	Max.	0.118	0.040	0.351	0.372	0.065	8.10	35.00	23.10	100.00	32.1	76.0
	% Missing	1.2	42.5	2.8	3.8	3.5	0.1	0.1	10.5	10.5	2.5	0.1
1985	Mean (ppm)	0.025	0.002	0.008	0.022	0.013	1.48	15.29	8.02	61.00	0.12	13.67
	Std. Dev.	0.020	0.002	0.018	0.026	0.010	1.20	9.64	10.58	19.46	0.98	20.27
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-21.10	-33.50	11.90	0.0	0.0
	Max.	0.119	0.026	0.268	0.307	0.108	10.00	34.80	22.70	98.40	36.1	78.0
	% Missing	3.0	71.2	24.5	16.4	31.2	0.0	0.8	35.3	35.3	1.1	1.6
1986	Mean (ppm)	0.025	0.002	0.010	0.023	0.015	1.44	15.53	5.18	57.05	0.11	13.34
	Std. Dev.	0.022	0.005	0.022	0.025	0.009	1.11	9.77	10.70	20.46	1.15	20.12
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-12.70	-26.30	10.60	0.0	0.0
	Max.	0.123	0.080	0.410	0.436	0.169	8.10	37.70	22.80	95.30	41.3	76.0
	% Missing	10.3	42.5	42.4	16.4	49.1	0.3	0.3	46.3	46.3	0.0	0.3
1987	Mean (ppm)	0.027	0.003	0.011	0.027	0.014	1.40	14.91	7.98	66.01	0.12	13.27
	Std. Dev.	0.022	0.004	0.028	0.034	0.009	1.23	9.88	9.88	20.06	1.11	19.88
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-8.90	-16.20	10.70	0.0	0.0
	Max.	0.112	0.054	0.375	0.391	0.059	8.20	37.70	24.40	100.00	64.2	80.0
	% Missing	10.2	13.3	41.6	31.5	41.3	0.8	0.1	1.5	1.2	0.1	1.7

*July through December data only.

TABLE 7B. SUMMARY STATISTICS FOR THE ENHANCED MAD FOR THE RESEARCH TRIANGLE PARK, NC, SITE

Year	Statistic	Variable										
		O_3	SO_2	NO	NO_x	NO_2	WSA	TEMP	DEW PT	RH	PR	SR
1982*	Mean (ppm)	0.023	0.001	0.009	0.020	0.011	1.28	16.77	12.39	77.57	0.12	12.72
	Std. Dev.	0.019	0.003	0.022	0.025	0.007	0.98	7.97	8.37	18.45	0.97	19.18
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	0.00	-12.20	24.60	0.00	0.00
	Max.	0.091	0.021	0.225	0.250	0.091	6.80	31.80	23.90	100.00	33.00	76.20
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
1983	Mean (ppm)	0.029	0.003	0.008	0.021	0.013	1.63	14.50	8.21	69.12	0.13	13.72
	Std. Dev.	0.023	0.004	0.019	0.023	0.008	1.30	10.12	9.84	20.36	0.85	20.89
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-16.00	-27.20	20.70	0.00	0.00
	Max.	0.143	0.048	0.295	0.312	0.073	10.00	38.70	24.40	100.00	22.00	78.00
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	Mean (ppm)	0.025	0.004	0.010	0.022	0.012	1.65	15.17	8.87	68.65	0.14	11.36
	Std. Dev.	0.021	0.003	0.024	0.029	0.010	1.20	9.31	9.87	19.34	1.01	17.56
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-12.70	-17.20	19.30	0.00	0.00
	Max.	0.118	0.040	0.351	0.372	0.119	8.10	35.00	24.40	100.00	32.10	76.00
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0
1985	Mean (ppm)	0.025	0.003	0.007	0.022	0.014	1.48	15.18	7.63	63.84	0.12	13.46
	Std. Dev.	0.020	0.002	0.016	0.024	0.014	1.20	9.69	10.54	20.36	0.98	20.18
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-21.10	-33.30	13.00	0.00	0.00
	Max.	0.119	0.026	0.268	0.307	0.268	10.00	34.80	22.80	100.00	36.10	78.00
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
1986	Mean (ppm)	0.025	0.002	0.008	0.022	0.015	1.44	15.51	9.31	70.28	0.11	13.31
	Std. Dev.	0.021	0.004	0.017	0.023	0.013	1.11	9.76	10.18	21.89	1.15	20.10
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-12.70	-22.80	15.70	0.00	0.00
	Max.	0.123	0.080	0.410	0.436	0.278	8.10	37.70	26.10	100.00	41.30	76.00
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	Mean (ppm)	0.026	0.003	0.010	0.026	0.016	1.40	14.91	8.63	69.63	0.12	13.27
	Std. Dev.	0.021	0.004	0.022	0.029	0.014	1.23	9.88	10.35	21.80	1.11	19.88
	Min.	0.000	0.000	0.000	0.000	0.000	0.00	-8.90	-20.60	10.40	0.00	0.00
	Max.	0.112	0.054	0.375	0.391	0.276	8.20	37.70	25.00	100.00	64.20	80.00
	% Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7

*July through December data only.